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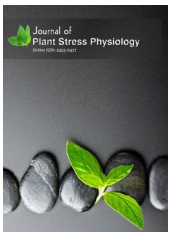
Research Article



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Evaluation of Hararge coffee (*Coffea arabica* L.) landraces for moisture stress tolerance

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ABSTRACT

Arabica Coffee is an important export commodity for Ethiopia, contributing 25 to 30 % of the country's total foreign exchange earnings. Moisture stress is one of the major constraints of coffee production in Hararge, Eastern Ethiopia. Moisture stress affects growth, yield and quality of coffee. Local coffee landraces are source of desirable traits including moisture stress tolerance. Accordingly, this study was conducted to evaluate Hararge coffee landraces for moisture stress tolerance. Treatments consisted of 200 coffee landraces (178 from seven district of east Hararge Zone and 22 from two districts of west Hararge Zone). The coffee landraces were field planted in July 2005 at Mechara Agricultural Research Center using augmented design with six trees per plot or accessions. Moisture stress tolerance was recorded from three randomly selected coffee trees per plot, three times a day (in the morning, noon and night) from January 05 to 25, 2014. The stress tolerance was determined using 1-5 scale by visual scoring (1- all leaves green and turgid, 2- most leaves still turgid but younger leaves show leaf folding; 3- all leaves wilt or fold, 4- Leaves partially turning pales, and partly shed showing severe wilting and 5-leaves completely turning brown and dry, mostly dropping). The collected data were analyzed using descriptive statistics. The result of this study revealed that the coffee landraces varied in their level of tolerance to moisture stress. The 200 coffee landraces were grouped in to seven clusters based on their level of tolerance to moisture stress. Nine coffee landraces (4.5%) were highly tolerant to moisture stress, 25 (12.5%) were tolerant, and 36 (18%) were moderately tolerant. On the other hand, 60 coffee landraces (30%) were less tolerant; while 57 (28.5%), 11(5.5%) and 2 (1%) were moderately sensitive, sensitive and highly sensitive to moisture stress, in that order. There was variation in coffee landraces for moisture stress tolerance both between and within areas of collection. Hence, it is advisable to maintain and use promising coffee landraces in coffee breeding. Screening of the landraces under controlled condition like green house and studying of mechanisms of moisture stress are also the way forward.

KEYWORDS: Coffee landraces; Eastern Ethiopia; Genetic diversity; Moisture stress

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INTRODUCTION

Coffee is an important export commodity for Ethiopia, contributing 25 to 30 % of the country's total foreign exchange earnings (National Bank of Ethiopia, 2019). The country is the leading coffee producer in Africa and 5th in the world (FAO, 2020). Coffee is a means of livelihood for one-fourth of the country's population. Ethiopia is the center of origin and diversity for Arabica coffee (Bayeta *et al.*, 2007). The coffee types of Ethiopia known for their very fine quality, unique aroma and flavor characteristics are Harar, Sidamo and Yirgacheffe types. Harar coffee is produced in West and East Harerghe Zones, eastern Ethiopia. Harar coffee accounted for 10% of the total country's coffee acreage and 8% of the country's coffee export. Harar coffee is grown in altitude ranging from 1510 to 2120 masl. In 2017, area devoted to coffee production in east Hararge Zone and west Hararge Zone were 7,584 and 7,746 ha, respectively. Coffee productivity was 0.5ton/ha in East Hararge and 0.6 ton/ha in west Hararge; and was below national average yield of 0.67 (Central Statistical Agency of Ethiopia, 2017).

In Hararge area, coffee is grown in garden production systems; intercropped with "chat" (*Chataedulis*), sorghum, maize, beans and sweet potato (Bayeta *et al.*, 2000). Hararge farmers grow coffee landraces having their own characteristic features. Total of 22 named local coffee landraces were recorded in Hararge areas (Demel and Assefa, 1994). In an effort to develop improved coffee varieties for the area, germplasm collection campaigns have been under taken since 1998. Following the establishment of Mechara Agricultural Research Center in Harerge in 2005, a large number of Hararge coffee collections previously collected (in 2002 and 2004) by the Jimma Agricultural Research Center have been maintained at Mechara center.

Moisture stress is one of the major constraints of coffee production in Hararge areas. The average annual rainfall of

coffee grower areas in Hararge Zones is 1100-1300 mm. the weather of the Hararge area is both hot and dry unlike other coffee producer areas in the country. Coffee requires optimum annual rainfall of 1200 to 1800 mm that is distributed over 9 months. Moisture stress affects growth, yield and quality of coffee (Silva *et al.*, 2005). Several researchers (Pinheiro *et al.*, 2005; Vieira *et al.*, 2013; Chemura *et al.*, 2014; Robel *et al.*, 2018; DaMatta *et al.*, 2018; Tesfaye *et al.*, 2019) reported presence of genetic variation in coffee for moisture stress tolerance. Local coffee landraces are heterogeneous and sources of desirable traits. Accordingly, this study was conducted to evaluate 200 Hararge coffee landraces for moisture stress tolerance.

MATERIAL AND METHODS

Experimental Site

The study was conducted in 2014 at the Mechara Agricultural Research Center, Eastern Ethiopia. The Center is located at $8^0$36'38.1" North latitude, $40^0$19'29.8" East longitude and at an altitude of about 1800 meter above sea level. It is situated at 434 km east of Addis Ababa and at 110 km south of Chiro, Zonal town. The soil of the center is deep, well-drained and slightly acidic nitosol, thus suitable for coffee production. The rainfall of the area is bimodal. The annual rainfall of the trial site is 1100 mm, of which about 85% is received from June to September and the remaining 15% is received from February to April. Severe dry weather occurs in December and January. The annual average minimum and maximum temperature of Mechara are 14^0C and 26^0C, respectively.

Treatment and Experimental Design

Treatments consisted of 200 coffee landraces. Total of 178 landraces were from seven districts of east Hararge Zone and 22 were from two districts of west Hararge Zone (Figure 1). Coffee landraces from east Hararge were collected from Deder (29), Melkaballo (46), Meta (52), Kurfachalle (20), Jarso (17), Kombolcha (6) and Haramaya districts (8). The 22 landraces from west Hararge Zone were collected from Tullo (21) and Doba districts (1). The 200 Hararge coffee landraces were field planted in July 2005 at Mechara Agricultural Research Center using augmented design with six trees per plot or accessions.

Data Collection and Analysis

Moisture stress tolerance was recorded three times a day (in the morning, noon and night) from January 05 to 25, 2014. The stress tolerance was determined from three randomly selected coffee trees per plotusing 1-5 scale by visual scoring. Scale1 was where all leaves were green and turgid, Scale2- most leaves still turgid but younger leaves show leaf folding; Scale3- All leaves wilt or fold, Scale 4- Leaves partially turning pales, and partly shed showing severe wilting and Scale5-leaves completely turning brown and dry, mostly dropping. The collected data were analyzed using descriptive statistics. The coffee land races were grouped based on their level of tolerance to moisture stress.

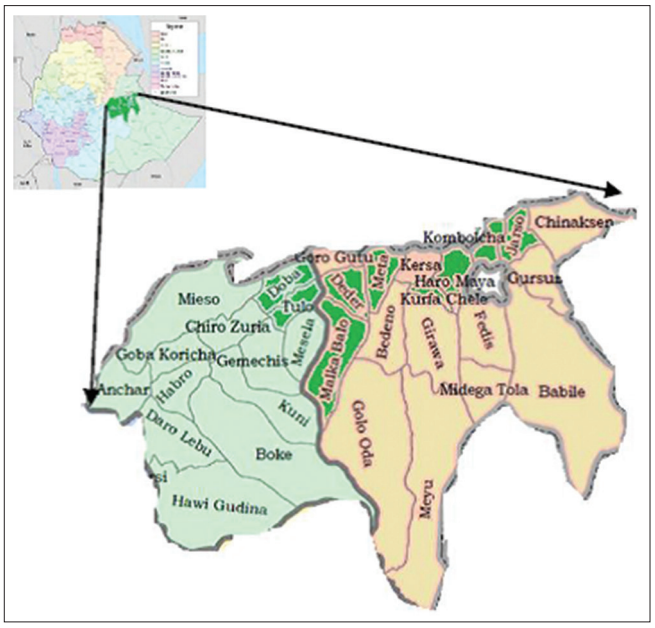

Figure 1: Map of coffee germplasm collection Districts (green shaded)

RESULT AND DISCUSSION

The coffee landraces varied in level of moisture stress tolerance (Table1). Nine coffee landraces (4.5%) were highly tolerant to moisture stress while 12.5% were tolerant. The proportions of moderately tolerant and less tolerant were 18% and 30%, respectively. On the other hand, 28.5% and 5.5% and 1% of the 200 coffee landraces were moderately sensitive, sensitive and highly sensitive to moisture stress, in that order. The nine highly moisture stress tolerant landraces (Table 2) were from Deder (1), Meta (3), Kurfachalle (3) and Jarso districts (2). Moisture stress tolerant coffee landraces were collected from Melkaballo (1), Deder (2), Meta (12), Kurfachalle (5), Kombolcha (2) and Jarso districts (3). On the other hand, moisture stress sensitive landraces were from Melkaballo (5), Jarso (1) and Tullo districts (5) while all of highly sensitive ones were from Meta district. This study revealed presence of coffee genetic variation among coffee landraces both between and within districts.

Coffee landraces from Deder and Kurfachelle districts varied from highly tolerant to moderately sensitive to moisture stress. Landraces from Melkaballo district ranged from tolerant to sensitive to moisture stress. On the other hand, landraces from Haramaya district were moderately tolerant (50%) and less tolerant (50%) while landraces from Meta district varied from highly tolerant (5.8%) to highly sensitive (3.8%) to the stress. Coffee landraces from the two districts (Tullo and Doba) of West Hararge Zone were from moderately tolerant to sensitive to moisture stress. In general Meta, Jarso, Kurfachalle and Deder districts are potential source of coffee germplasm for moisture stress tolerant coffee variety development in future breeding work.

The results of previous studies also revealed presence of variation among coffee genotypes for drought tolerance. For instance, Tesfaye *et al.* (2019) reported presence of variation in tolerance

Table 1: Clustering of coffee landraces based on moisture stress tolerance

Scale	No.	% to Total	List of coffee landraces						
1.00-1.49	9	4.5	H-759	H-673	H-706	H-33	H-698		
			H-636	H-697	H-786	H-639			
1.50-1.99	25	12.5	H-91	H-80	H-760	H-671	H-624	H-627	H-572
			H-679	H-674	H-625	H-680	H-672	H-637	
			H-699	H-755	H-748	H-62	H-749	H-640	
			H-789	H-705	H-676	H-678	H-93	H-734	
2.00-2.49	36	18.0	H-632	H-580	H-769	H-761	H-27	H-51	
			H-53	H-638	H-793	H-626	H-247	H-54	
			H-67	H-758	H-570	H-55	H-666	H-403	
			H-756	H-768	H-582	H-573	H-733	H-669	
			H-28	H-571	H-581	H-583	H-22	H-736	
			H-747	H-667	H-670	H-17	H-34	H-743	
2.50-2.99	60	30.0	H-387	H-386	H-575	H-777	H-645	H-25	H-203
			H-574	H-545	H-584	H-13	H-651	H-50	H-236
			H-49	H-585	H-641	H-192	H-655	H-588	H-656
			H-623	H-42	H-665	H-382	H-714	H-611	H-660
			H-648	H-630	H-87	H-562	H-717	H-643	H-642
			H-160	H-716	H-137	H-576	H-719	H-658	H-659
			H-231	H-668	H-599	H-595	H-735	H-762	
			H-644	H-744	H-647	H-601	H-01	H-568	
			H-10	H-547	H-385	H-622	H-18	H-05	
3.00- 3.49	57	28.5	H-202	H-383	H-551	H-396	H-603	H-631	H-544
			H-567	H-390	H-653	H-400	H-605	H-565	H-347
			H-633	H-586	H-737	H-597	H-650	H-657	H-394
			H-646	H-596	H-08	H-168	H-779	H-377	H-652
			H-713	H-649	H-14	H-346	H-16	H-661	H-09
			H-778	H-654	H-32	H-393	H-548	H-662	H-783
			H-23	H-602	H-161	H-536	H-552	H-195	H-569
			H-191	H-04	H-340	H-566	H-663	H-540	H-402
3.50- 3.99	11	5.5	H-345	H-366	H-612	H-795	H-614	H-401	
			H-348	H-621	H-365	H-587	H-620		
≥4.00	2	1.0	H-634	H-635					
total	200	100.0							

Key: 1.00-1.49 indicates highly tolerant; 1.50-1.99 tolerant; 2.00-2.49 moderately tolerant; 2.50-2.99 less tolerant; 3.00- 3.49 moderately sensitive, 3.50- 3.99 sensitive and ≥4.00 highly sensitive to moisture stress

Table 2: Distribution of coffee landraces by level of moisture stress tolerance and district

District	Number of coffee landraces by stress tolerance scale and district							Total
	1.00-1.49	1.5-1.99	2.0-2.49	2.50-2.99	3.00- 3.49	3.5- 3.99	≥4.00	
Melkaballo		1	7	16	17	5		46
Deder	1	2	10	9	7			29
Meta	3	12	7	16	12		2	52
Kurfachalle	3	5	4	6	2			20
Haramaya				4	4			8
Kombolcha		2		3	1			6
Jarso	2	3	6	2	3	1		17
Tullo			1	4	11	5		21
Doba			1					1
Total	9	25	36	60	57	11	2	200

Key: 1.00-1.49 indicates highly tolerant; 1.50-1.99 tolerant; 2.00-2.49 moderately tolerant; 2.50-2.99 less tolerant; 3.00- 3.49 moderately sensitive, 3.5- 3.99 sensitive and ≥4.00 highly sensitive to moisture stress

to moisture stress in 10 coffee varieties at Tepi, Robel *et al.* (2018) in 15 Arabica coffee genotypes from Hararge, King'oro *et al.* (2014) in 11 coffee genotypes from western Kenya and Chemura *et al.* (2014) in four coffee varieties from Zimbabwe. In recent study, Tesfaye *et al.* (2020) who evaluated coffee varieties under low moisture stressed areas of southern Ethiopia also reported presence of variation among coffee genotypes in tolerance to moisture stress. Drought tolerance in coffee is due to morphological factors like rooting depth (Pinheiro *et al.*, 2005), physiological including stomatal control of water use (DaMatta *et al.*, 2018), different molecular mechanisms (Vieira *et al.*, 2013) and biochemical such as proline content (Wubishet, 2019). Interestingly, candidate genes for drought tolerance were identified in coffee by high-throughput sequencing in the shoot apex of different *Coffea arabica* cultivars (Mofatto *et al.*, 2016). Hence, it is advisable to maintain drought tolerant and promising coffee landraces identified in the present study for utilization in future coffee breeding for moisture stress tolerance.

CONCLUSION AND RECOMMENDATION

The result of this study revealed that Hararge coffee landraces varied in moisture stress tolerance. Of 200 coffee landraces, nine (4.5%) were highly tolerant and 12.5% were tolerant to moisture stress. The proportions of moderately tolerant and less tolerant were 18% and 30%, respectively. On the other hand, 28.5% and 5.5% and 1% were moderately sensitive, sensitive and highly sensitive to moisture stress, in that order. There was variation both between and within areas of collection. Hence, it is advisable to maintain and utilize promising landraces in coffee breeding for moisture stress tolerance.Screening of the landraces under controlled condition like green house and studying of mechanisms of moisture stress are also the way forward.

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